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QUARTERLY PROGRESS REPORT

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Bellcomm, Inc.

Report No. 67-101-3
Contract NASW-417

BELLCOMM, INC.

QUARTERLY PROGRESS REPORT

April May June

1967

W. C. Hittinger
President

BELLCOMM, INC.

Washington, D. C.

Report No. 67-101-3
Contract NASW-417

QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm, Inc., during the quarter ending June 30, 1967 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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BELLCOMM, INC.

QUARTERLY PROGRESS REPORT

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Table of Contents

APOLLO SYSTEMS ENGINEERING STUDIES

Mission Planning	1
Requirements	4
Configuration	7
Scientific Studies	11

APOLLO APPLICATIONS SYSTEMS ENGINEERING STUDIES

Mission Planning	13
Requirements	14
Configuration Studies	16
Scientific Studies	18

SPECIAL TASK ENGINEERING STUDIES

Assistance in Certain Computer Operations - Task Order No. 12	19
MSF Experiments Program Studies - Task Order No. 27	20
Data Processing for Advanced Manned Missions - Task Order No. 28	21
MSF Computer Utilization Study - Task Order No. 31	22
Advanced Lunar Mission Studies - Task Order No. 32	23
Planetary Mission Studies - Task Order No. 33	27

GENERAL MISSION ENGINEERING STUDIES	32
ENGINEERING SUPPORT	33
ADMINISTRATIVE	34
LIST OF REPORTS AND MEMORANDA	35

APOLLO SYSTEMS ENGINEERING STUDIES

MISSION PLANNING

Apollo Flight Mission Assignments

A draft of the "Apollo Flight Mission Assignments" document covering the revised primary flight program was prepared and presented to the Apollo Program Director for review. The draft reflects results of efforts to determine revised primary objectives, payload interface weights and the backup missions which may be required in support of the primary flight program.

Work was initiated to update the document, "Apollo Flight Program Description Including Contingencies" to reflect the revised flight program.

Inclusion of propellant removal in orbit as an operational test on Apollo 5 (formerly AS-204) was coordinated with MSFC. Results were presented to the Apollo Program Office and reported in a Configuration Control Board (CCB) directive.

Vehicle Performance

Coordination with MSC and MSFC on the action items from the MSF Weights and Performance Meeting of May, 1967, was completed. Approval was obtained from the Apollo Program Office to change the control payload for lunar landing missions to 98,000 pounds. Coordination was completed on an agreement covering procedures for transferring up to 2000 pounds across the launch vehicle/spacecraft interface. The transfer may be accomplished prior to fueling time without re-optimizing the trajectory.

A study was performed to confirm the amount of payload loss that would result from canting the outboard engines on the S-IC stage. (1)

The Quarterly Weight and Performance Report, and the Weight and Performance Summaries for April and May were prepared and delivered to the Apollo Program Office for publication.

Development Missions

The Apollo 4 mission (formerly AS-501) was examined to determine spacecraft impact locations resulting from launch vehicle and spacecraft propulsion system failures. (2) It was found that no land impacts result from a single

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(1) Investigation of Payload Effect of Canting the S-IC Engines, Memorandum for File, W. R. Thomson, May 25, 1967.

(2) Summary of Apollo 4 (AS-501) Spacecraft Impact Points, Memorandum for File, R. E. Driscoll, June 26, 1967.

propulsion system failure. Summaries were presented at the April and June Apollo Program Office Reviews.

Trajectory Analysis

The constraints placed on LM attitude during ascent and descent by a requirement for continuous LM-Earth communications using the steerable S-Band antenna were analyzed.[3] It was concluded that a pilot-controlled yaw maneuver sufficient to maintain communications is the most workable solution. The requirement for such a maneuver was found to be largely dependent on the lunar landing date and the landing site. The maneuver was shown to cause no interference with landing radar operations for the candidate sites of the first lunar landing mission.

An analytical simulation for studies of deboosting into a specified lunar parking orbit with two burns was incorporated into the Bellcomm Apollo Simulation Program. The simulation is being utilized to investigate further the effects of two-burn deboosts on lunar landing site accessibility.

A study of the correlation between lighting at lunar landing and the lighting at earth launch was completed.[4] With the current lunar lighting constraint, a large majority (upwards of 90%) of daylight launches require use of a Pacific launch window. This result is inherent in the earth launch geometry and is valid for the entire 18.6 year lunar cycle. The memorandum included formulae and graphs which permit the calculation of lighting conditions at earth launch for any lunar lighting constraint.

Mission Variability

The interactions between the launch azimuth limits, the length of the launch window, the launch vehicle payload capability, and communications and tracking coverage were examined for lunar missions.[5] It was shown that when mission constraints restrict launch azimuth to a subsector of the total azimuth range, the available launch window is a strong function of the placement of the subsector within the total range. The optimum placement was defined as a function of lunar declination. The loss in payload capability as a function of azimuth subsector width was illustrated as was the tracking coverage for various launch azimuths.

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(3) LM-Earth S-Band Communications for Powered Descent and Ascent Phases of the Lunar Mission, TM-67-2013-3, A. C. Merritt, May 15, 1967.

(4) The Influence of Earth Launch and Lunar Lighting Constraints on the Apollo Mission, TM-67-2013-4, L. P. Gieseler, May 26, 1967.

(5) The Effects of Changing the Launch Azimuth Limits on the Launch Window, Launch Vehicle Payload, and Communications and Tracking Coverage, Memorandum for File, T. B. Hoekstra, April 6, 1967.

Guidance Analysis

Study of the Launch Vehicle, Command Module, and Lunar Module guidance and control equations continued. An Apollo 4 Launch Vehicle Error Analysis showed no particular problems for that mission. (6) It disclosed an approximate method of analysis which makes changes particularly easy to evaluate for this and future missions. A study of translunar midcourse correction requirements delineated the important factors and showed that the correlations between the various orbital parameters should be included in such analyses. (7)

A study of the Entry Monitoring System was initiated. It considers both the monitoring and trajectory control effectiveness of the system.

A study of the Lunar Orbiter tracking data was initiated to compare the noise of the Deep Space Instrumentation Facility to that of the Manned Space Flight Network (MSFN).

Mission Rules and Flight Plans

The Apollo 4 Preliminary Launch Mission Rules and the Apollo 5 Flight Plan were reviewed and comments were transmitted to the Apollo Program Office.

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(6) Launch Vehicle Error Analysis for Apollo/Saturn 501(U), BTL-R-67-310-1, Bell Telephone Laboratories, April 14, 1967, CONFIDENTIAL.

(7) Midcourse Correction Penalties Due to Expected Translunar Injection Deviations, TM-67-2012-2, D. A. Corey, B. G. Niedfeldt, June 14, 1967.

REQUIREMENTS

Apollo Program Specification

Specification changes to update the Saturn V series launch vehicle payload capability and the CSM and LM propulsion systems capability were delivered to the Apollo Program Office Configuration Control Board (CCB). These changes were subsequently approved and issued.

Work continued on preparation of specification changes to reflect decisions made as a result of the AS-204 accident.

Lunar Surface Models

An analysis defining three lunar surface models was completed.[8] The first model describes the worst-acceptable surface properties which determine the mechanical interaction of the LM with the surface. The second model describes the worst tolerable distribution of acceptable surface in the vicinity of the landing point. Both of the above models define the operational capability of the LM and are in a format suitable for inclusion in the document "Natural Environment and Physical Standards for the Apollo Program". The third model is derived from the first two and represents a more hospitable environment appropriate for the first lunar landing mission.

Unified S-Band (USB) Systems Studies

A review of Apollo USB communication system margins was completed.[9] Using the deep space stations of the MSFN, full channel performance at lunar range appears adequate with the spacecraft directional antennas. Either voice or low bit rate telemetry can be provided when using the spacecraft omnidirectional antennas.

An analysis of the pointing error in the LM directional antenna with an up link signal that includes the ranging code has shown that a change in modulation indices would eliminate the difficulty. A set of revised modulation indices was prepared and transmitted to MSC for experimental verification.

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(8) Lunar Surface Models for Apollo, Memorandum for File, W. W. Ennis. F. Heap, April 24, 1967.

(9) Apollo S-Band Communications Capabilities Using High Power RF Modes with Directional and Omnidirectional Antennas, TM-67-2034-3, R. L. Selden, April 26, 1967.

Other Communications Studies

An analysis was completed which developed a mathematical model of the performance of the Apollo USB transponder when used in the turn-around mode. (10) This model also provides a basis for analysis of relay systems such as the LM relay experiment in the Apollo Applications Program (AAP) and a data relay satellite system for future manned missions.

Launch Complex Voice Communication

Problems experienced with the Operational Intercommunications System (OIS) on Launch Complexes 34 and 37 led to plans to improve the capability for communication during tests and launch operations. A method for conversion of critical circuits of the existing OIS from a 2-wire to a 4-wire configuration was developed to accomplish this objective. (11)(12) The replacement of headset transducers with more efficient types was also recommended to improve frequency response, intelligibility, and resultant operational efficiency.

Apollo 4 RF Margin Studies

An evaluation of circuit margins for the high altitude portions of the Apollo 4 mission was completed. (13) The evaluation was confined to the CSM USB system and the IU Command and Communication System (CCS) and showed that there were two periods of marginal CSM telemetry signal strength. The first was a brief period shortly after the first SPS burn and the second was a longer period near apogee.

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(10) Spectral Analysis of a Communications Relay System Using an Apollo Unified S-Band Transponder, TM-67-2034-4, W. D. Wynn, June 30, 1967.

(11) A Plan for Modifications to the Voice Conferencing Arrangements at Kennedy Space Center, Bell Telephone Laboratories, Attachment A to J. Z. Menard Memorandum to W. E. Parsons-NASA/MJ of June 16, 1967.

(12) KSC Conferencing System - Analysis of Transmission, May 26, 1967, Bell Telephone Laboratories, Attachment B to J. Z. Menard Memorandum to W. E. Parsons-NASA/MJ of June 16, 1967.

(13) Unified S-Band Circuit Margins for the High-Altitude Phase of Mission AS-501, Memorandum for File, J. E. Johnson, J. P. Maloy, June 15, 1967.

Apollo Ground Communications

An algorithm was developed concerning the loading of the Communications, Command and Telemetry System (CCATS) Univac 494 computers at the Mission Control Center-Houston (MCC-H).[14] The algorithm is capable of determining the CCATS capabilities and limitations for Apollo missions with respect to character transfer, processing, and storage.

It was determined that the current reliability data on the Goddard Space Flight Center Message Switching Center communications processor in the redundant mode of operation is not indicative of the Center's ability to provide uninterrupted support during critical periods of an Apollo mission; the current data are on single machine operation, while Apollo will require dual operation at discrete periods in the mission such as insertion and lunar launch. A measure of reliability termed "operational success" has been considered as an alternate method of evaluation.

Human Standards

A draft of the Apollo Human Standards (Flight Crew) document was circulated to members of the Human Standards Working Group and NASA contractors for review.

Flight Planning

Five meetings were held with MSC flight planning personnel to discuss the results of analyses of requirements and constraints for flight planning. A draft report of the study results was provided to MSC for comment.

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(14) Communications Processor Loading Studies MCC-H, CCATS UNIVAC 494 Algorithm, Memorandum for File, R. M. Marella, Bell Telephone Laboratories, April 10, 1967.

CONFIGURATION

Launch Systems

The principal Electrical Support Equipment (ESE) systems used for Saturn launches were examined with regard to the impact of failures and the availability of an alternate support capability during critical operations. (15) It was found that nine systems classified as "mandatory" in the Apollo 4 Mission Rules do not incorporate complete redundancy or alternate support provisions.

A study was made of the effect on lunar launch opportunities of returning the Space Vehicle to the Vehicle Assembly Building (VAB). Required intervals for several cases were developed for planning purposes. (16)

LM hold and recycle capabilities were examined for the first lunar landing mission. No items were found which would be pacing constraints on missions presently being planned. (17)

Preliminary plans for LM subsystems monitoring after launch pad closeout were examined. It appears that implementation of the plans will provide adequate data points for evaluating the status of critical items. (18)

Space Vehicle

Partial cabin depressurization coupled with the replacement of the spacecraft atmosphere by a diluent gas was examined as a strategy for dealing with spacecraft fires in flight. (19)

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(15) Failure Impact and Backup Capability of Saturn Launch Support ESE at KSC, TM 67-2032-2, V. Muller, June 5, 1967.

(16) Influence of Space Vehicle Returns to the VAB on Lunar Launch Opportunities, Memorandum for File, D. M. Duty, C. H. Eley III, April 3, 1967.

(17) LM Hold and Recycle Capabilities for Launch Complex 39, Memorandum for File, D. M. Duty, June 19, 1967.

(18) LM Subsystem Monitoring After Pad Closeout - Apollo/Saturn V, Memorandum for File, D. M. Duty, April 10, 1967.

(19) A Parametric Study on the Use of Diluent Gases as a Means of Extinguishing Spacecraft Fires in Flight, TM 67-2032-1, L. G. Miller, April 17, 1967.

Descriptive memoranda on the S-IC propellant and propellant pressurization systems, the S-II systems and S-II structure were prepared.[20,21,22]

Continuing technical assistance was provided to NASA in support of flight safety/space emergency efforts.

Assistance to the Apollo Program Office continued in describing, monitoring and assessing proposed spacecraft and launch systems changes resulting from the Apollo 204 accident.

A survey and evaluation of current techniques for joining tubing used in the spacecraft was conducted.[23] The need for improved mechanical fasteners and improved flaring machines (such as used on the S-II stage) was noted. The possible advantages of brazing of aluminum tubing after its installation in the spacecraft and of detecting stress in solder joints were also cited.

A review of safety factors for flight system pressure vessels was initiated. Materials technology, vessel design, pedigree and test data, and operating conditions and environments were examined for spacecraft vessels used at factors of safety below 2.0. A number of suggestions were developed for reducing the exposure of ground personnel during initial pressurization tests conducted in the launch area. It was also emphasized that there is a need to better define the actual pressure capabilities of vessels fabricated for flight and the specific pressure levels to be encountered during flight. The review is being expanded to include consideration of safety factors and potential failure mechanisms for propellant tanks in the Saturn Launch Vehicles.

A detailed plan for subjecting a small number of Apollo Guidance Computers to dynamic noise margin tests was prepared, and a method for evaluating the test results suggested.[24]

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(20) A Description of the S-IC Stage Propellant and Propellant Pressurization Systems, Memorandum for File, S. H. Levine, April 20, 1967.

(21) Description of S-II Stage Systems, Memorandum for File, T. H. Crowe, April 21, 1967.

(22) Description of S-II Stage Structures, Memorandum for File, T. H. Crowe, April 20, 1967.

(23) Discussion with MSC on Environmental Control System Tubing Joints, April 27, 1967, Memorandum for File, S. S. Fineblum, May 2, 1967.

(24) Experiment for Evaluating a Dynamic Noise Margin Test for the Apollo Guidance Computer, Memorandum for File, J. J. Rocchio, April 13, 1967.

The study of memory requirements for the Saturn Launch Vehicle Digital Computer (LVDC) was continued in support of MSFC. The LVDC memory planned for the AS 500-series flights consists of eight 2,000-word modules duplexed i.e., 32000 words, the maximum capacity of the machine. The study concluded that the expected reserves - 18% of total memory capacity for Apollo 4 and 11% of AS-504 - were inadequate margins for possible contingencies or new requirements. It was recommended that certain memory savings obtainable by reprogramming be implemented. This would increase reserves on Apollo 4 and AS-504 to 31% and 24% respectively.(25) It was further concluded that if these savings are implemented, the high priority development of an auxiliary memory unit (AMU) would not be required. The need and timing for production of an AMU would depend on AAP LVDC requirements.

A review of the LM electrical power system revealed a possible compatibility problem when the LM is docked to the CSM and the two power systems are connected. This was reported to MSC.

The LM-1 Configuration Review briefing book which was prepared for the Apollo Program Director in the first quarter was updated for use at the LM-1 Customer Acceptance Readiness Review (CARR). Revised information for the Apollo Status Center was prepared to reflect recent changes in LM configurations.

A study was made of existing capability to power-down the Command Module in an emergency. It was found that total powering-down is not feasible and that further effort will be required to develop the most effective partial powering down precedures.

A draft description of the major differences between the Block I and Block II spacecraft was prepared.

Launch Vehicle

A summary of significant differences in the configuration of successive Uprated Saturn I launch vehicles was prepared with the assistance of MSFC for incorporation in the Apollo Status Center charts.

A review of hardware changes proposed to shorten the interval prior to restart of the S-IVB J-2 engine was completed in conjunction with the Apollo Test Directorate of the Apollo Program Office. It was concluded that a capability to restart in 80 minutes and thus achieve all second orbit injection opportunities was probably obtainable with the present configuration. Decreasing this interval to about 35 minutes to achieve all Pacific first orbit opportunities would require several hardware modifications.(26)

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(25) Memory Requirements for the Launch Vehicle Digital Computer (LVDC), Memorandum for File, J. J. Rocchio, April 25, 1967.

(26) S-IVB/J-2 Engine Restart, Memorandum for File, A. T. Ackerman, May 15, 1967.

A review was completed of current MSFC studies concerning the capability of the Saturn V launch vehicle to withstand structural loads to allow safe abort in case of certain engine-out failures in combination with high wind loads. It was concluded that the MSFC plan to strengthen certain structural joints in conjunction with wind biasing trajectories and a reduced safety factor for the worst case appeared to be acceptable.(27)

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(27) Saturn V Launch Vehicle Engine-Out and Ground Wind Structural Capability, Memorandum for File, H. E. Stephens, April 11, 1967.

SCIENTIFIC STUDIES

Space Environment

Radiation Environment

Space radiation effects on the Apollo Optical Astrosextant and Scanning Telescope were examined.(28) Three sources of radiation doses were considered: solar wind, solar cosmic rays, and the Van Allen belts. The evidence indicated that there is no significant problem resulting from radiation darkening of the optical system.

Intravehicular Environment

Methods of analyzing the composition of space cabin atmospheres were reviewed.(29) The mass spectrometer appears to have some advantages for general trace gas analysis, particularly during long duration space flight where the buildup of contaminants could present a health hazard.

Lunar Studies

Lunar Landmarks for Apollo

Results of continued technical analysis of Apollo navigational needs for lunar surface position data were reviewed with MSC.

The problem of uncertainties in lunar surface position data for features used to locate candidate Apollo landing sites was examined. Preliminary analysis of Lunar Orbiter data indicates significant position uncertainties when maps made from telescopic data are compared to positions derived from tracking data.(30)

Lunar Orbiter

Technical support of mission planning for Lunar Orbiter V included analysis for oblique photography and detailed targeting for the Apollo sites.

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(28) Radiation Effects in the Optical Elements of the Apollo Astrosextant and Scanning Telescope, Memorandum for File, R. H. Hilberg, April 20, 1967.

(29) Analysis of Space Cabin Atmospheres, Memorandum for File, A. E. Hedin, May 4, 1967.

(30) Lunar Surface Coordinate Data for Apollo Guidance, Memorandum for File, D. D. Lloyd, May 5, 1967.

Surveyor

The preliminary results of the Surveyor III mission were interpreted in terms of an Apollo lunar landing. [31]. A second Surveyor landing within Oceanus Procellarum has increased the confidence in the intergrity of this area to support a Lunar Module and walking astronauts. Support of future Surveyor missions continued to ensure compatibility with the needs of Apollo. Targeting recommendations were made for the Surveyor D missions as well as later missions when landings in eastern Mare Tranquillitatus may be possible.

Estimates of the lunar co-ordinates of Surveyor I derived from four data sources were examined. [32] The differences in location were larger than expected.

Data Analysis

A study of optical data processing was completed. [33] It appears that the efficiency of photographic analysis can be greatly improved by using analog techniques instead of digital methods. However, considerable research and development effort will be required. In response to a NASA request a proposed statement of work covering this effort was drafted and transmitted to the Apollo Program Office.

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(31) The Surveyor III Mission and Its Relation to Apollo, Memorandum for File, F. N. Schmidt, June 19, 1967.

(32) Lunar Co-ordinates of Surveyor I, Memorandum for File, C. J. Byrne, April 28, 1967.

(33) Optical Data Processing and Terrain-Hazard Analysis of Lunar Orbiter Photographs, Memorandum for File, V. B. Schneider, May 8, 1967.

APOLLO APPLICATIONS SYSTEMS ENGINEERING STUDIES

MISSION PLANNING

A draft Apollo Applications Flight Mission Assignments Directive was prepared to assist in implementing program decisions regarding early Apollo Applications Program (AAP) flights. This draft has been reviewed by the Saturn Apollo Applications Office and is being updated to reflect current concepts. In support of this directive the list of approved experiments was reviewed and reassignments suggested.[34]

The weight and performance status of the early AAP missions was under continuing review during the quarter. Possible mission profile changes to permit solution to overweight problems were analyzed.[35] This work resulted in an overall weight and performance review conducted by the Program Director on May 24 and in action items leading to the alteration of baseline configurations and missions.

Participation in the Mission Requirements Panel and Subpanel meetings, in the Flight Operations Plan meetings and in the Experiment Management Group was continued in support of the definition of early AAP missions.

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(34) AAP Experiment Assignments, Memorandum for File, M. S. Feldman, June 27, 1967.

(35) Orbital Altitude Considerations for AAP-4, Memorandum for File, V. J. Esposito, April 5, 1967.

REQUIREMENTS

A draft of "Apollo Applications Program Baseline Configuration Definition, AAP-1A through AAP-5" dated June 1, 1967 was prepared and subsequently issued by the Apollo Applications Program Director. As the program matures the document will be updated and will eventually form the basis for a program level specification.

Participation was provided in the Orbital Workshop Preliminary Design Review. The progress of the action items assigned at that review is being followed.

An analysis was completed of the coverage by the Manned Space Flight Network for the vehicles of AAP missions 1-4.[36] In terms of the number of contacts per time interval, little if any coverage impact results from increasing the orbital inclination. The cumulative contact time does decrease, however, as the inclination is increased.

A review was completed of the space vehicle-ground data links currently being planned for implementation on the space vehicles to be used in AAP missions 1-4.[37] This evaluation indicated that the ground network is not capable of supporting all of the spacecraft-to-MSFN data links if simultaneous data from all of them are required to operate the missions. Some possible combinations of these links were suggested to minimize the ground station data processing problem.

The study of experiments data flow for AAP continued. A draft of a data flow plan is in preparation. A memorandum describing the processing of spacecraft experiments data at the Goddard Space Flight Center (GSFC) was issued.[38]

In support of MSFC, the Launch Vehicle Digital Computers (LVDC) for both the early and later AAP missions were studied. It was concluded that the current Uprated Saturn I 6-module (duplexed) memory will probably be sufficient for AAP missions 1-5. The memory has the capability of being expanded to

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(36) Coverage Analysis of Missions AAP-1 through AAP-4 Using Orbit Inclination as a Variable, Memorandum for File, A. G. Weygand, May 9, 1967.

(37) Summary of the Data Links from the Apollo Applications Spacecraft to the Manned Space Flight Network for AAP Missions 1-4, Memorandum for File, R. L. Selden, June 30, 1967.

(38) Data Handling at the GSFC Telemetry Data Processing Facility, Memorandum for File, R. J. Pauly, April 28, 1967.

8 modules, and this may become necessary as mission requirements are better defined. However, it was considered unlikely that an auxiliary memory unit would be needed for these early missions. LVDC memory requirements for later missions will depend heavily on whether or not the liftime of the Instrument Unit is extended. (39)

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(39) Launch Vehicle Digital Computer (LVDC) Requirements for the Apollo Applications Program, Memorandum for File, J. J. Rocchio, June 20, 1967.

CONFIGURATION STUDIES

Earth Orbital Systems

Study efforts are continuing on the comparison of inertial and gravity-gradient flight attitude alternatives for mission AAP 1/2. Current program planning is based on a gravity-gradient mode. However, the inertial option offers two significant advantages:

a. Realization of the full electrical power and energy potential of the S-IVB Workshop solar array

b. Permits a common Workshop thermal design for missions AAP 1/2 and 3/4.

Methods of providing an inertial attitude that have minimum system impact are under study. One approach, based on utilization of the CSM RCS system in a new mode, termed quasi-inertial stabilization, has been reported.(40) Results indicated that this approach offers the possibility of obtaining high efficiency from fixed solar panels with relatively low RCS fuel consumption.

The problem of momentum accumulation in the Control Moment Gyro (CMG) system for AAP 3/4 was investigated.(41) Two cluster configurations were studied, the LM/Apollo Telescope Mount (ATM) docked to a side port of the Multiple Docking Adapter (MDA) with the CSM docked to an axial port, and the LM/ATM docked to a side port of the MDA with the CSM docked to a perpendicular side port. The results showed the peak accumulated momentum on successive orbits due to gravity-gradient and aerodynamic torques. It was shown that desaturation of the CMG system should be required no more frequently than once every five orbits.

A study was performed on the mission modes in which the LM/ATM is tethered to the cluster.(42)(43) The study identified the possible combinations and permutations of vehicle attitudes for inertial and gravity gradient stabilized systems. It also investigated the problems associated with possible wrap-up of a flexible tether and the use of a rigid tether or boom.

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(40) Quasi-Inertial Stabilization of the AAP 1/2 Cluster Configuration, TR-67-600-3-1, B. D. Elrod, April 14, 1967.

(41) Accumulation of Momentum and CMG Loading for Two Cluster Configurations, Memorandum for File, C. O. Guffee, May 15, 1967.

(42) Tethered LM/ATM Modes for AAP 3/4, Memorandum for File, J. Kranton, April 10, 1967.

(43) Tether Management Considerations for AAP-4, TM-67-1022-1, W. W. Hough, April 13, 1967.

Lunar Systems

Support was provided to the Apollo Applications Lunar Missions Ad Hoc Study Team, formed to consider the first five AAP lunar missions. Results of this study were presented in a briefing for the Director of the Saturn/Apollo Applications Office on June 30.(44) The range of candidate derivatives available from Apollo and new production Lunar Modules was examined for feasibility, performance, and application to the early missions. Program and science objectives, mission profile and trajectory constraints, and Saturn V injection capability were considered. Major study effort was focused on the following concepts:

1. Extended LM - primary application in improved single-launch missions of retrofit Apollo LM's, assuming confidence from early Apollo landings and the existence of Apollo growth potential in margins, constraints, and profiles (3 day lunar staytime capability).

2. Dependent LM/Lunar Payload Module - early, extended duration, dual-launch missions of retrofit Apollo LM's using a pre-landed "Logistics LM" to provide science payload and external resupply of the manned/dependent LM (12-14 day lunar staytime capability).

3. Augmented LM - new production LM for improving single-launch mission capability by uprating descent engine, tanks, and stage structure (8 - 14 day lunar staytime capability).

Several related studies were performed and presented to the Study Team, including LM/ATM commonality, subsystem requalification, CSM requirements, SPS and Saturn V limitations, LM helium duration limits, LM residual propellants for lunar flying vehicles, Apollo spacecraft and launch vehicle baseline values, and recommendations for an augmented Apollo system study.

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(44) Spacecraft Presentation - AAP Lunar Mission Ad Hoc Study Team, Memorandum for File, J. E. Waldo, July 6, 1967.

SCIENTIFIC STUDIES

Radiation Environment

Radiation doses expected during the AAP missions 1-4 were estimated.(45) These were based on both the latest tabulation (1964) of flux intensities, and on intensities predicted for 1968 using observed decay rates for the artificial electrons. While dose rates derived from 1964 flux intensities are somewhat restrictive because of limited LM shielding, dose rates projected for 1968 impose no operational constraints.

A model of the trapped electron radiation environment at near synchronous altitudes was developed and problems associated with long duration manned missions at these altitudes were assessed.(46)

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(45) Radiation Dose Calculations for AAP Cluster A Missions, Memorandum for File, R. H. Hilberg, May 11, 1967.

(46) Variation in Radiation Dose Rate with Altitude and Shielding Thickness at Orbits Near Synchronous, TM-67-1021-1, T. C. Tweedie, Jr., May 23, 1967.

SPECIAL TASK ENGINEERING STUDIES

ASSISTANCE IN CERTAIN COMPUTER OPERATIONS AND RELATED ACTIVITIES

TASK ORDER NO. 12

During the period of April 1, 1967 through June 30, 1967, NASA usage of the 7044 computer was 105.31 hours. There was no independent usage (non-BCMSYS) of the 7040 computer during this time.

MANNED SPACE FLIGHT EXPERIMENTS PROGRAM

TASK ORDER NO. 27

Astronomical Instruments

The principal limitations on the angular resolution of optical telescopes were reviewed to assess their relative importance for future orbiting telescopes.(47) In order to take full advantage of being above the atmosphere and to achieve the ultimate diffraction-limited resolution permitted by the wave nature of light, all other aberrations must be held to very low levels. The most difficult problems for large space telescopes will probably involve the attainment of accuracy of a quarter wave length or better in the gross mirror figure, and adequate optical system alignment and pointing stability under flight conditions.

Long Range Experiment Program Planning

A study is under way to identify the principal elements of a time-phased experiment program for the next twelve years in a manner which follows a logical development and gives proper emphasis to all disciplines involved. Sources include recommendations from the National Academy of Sciences, the President's Science Advisory Committee, other contractor studies, and the Manned Space Flight Experiments Catalog which lists all known experiments proposed for manned space flight. A large program of experiments in many fields is warranted both because of the new scientific opportunities afforded by the space environment and because of the need for developing further space capabilities. Astronomy, earth applications, and the development of long duration manned flight capability should be the prime components that pace the entire experiment program.

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(47) Limitations on Angular Resolution of Optical Telescopes, Memorandum for File, A. E. Hedin, June 6, 1967.

DATA PROCESSING FOR ADVANCED MANNED MISSIONS

TASK ORDER NO. 28

A survey of the state-of-the-art of aerospace digital computers for the 1962-1967 period was completed.[48] Characteristics of 40 machines were examined and collated. It was found that each characteristic has a fairly wide range, reflecting the variety of computers available to meet a variety of applications. One trend in the overall design of aerospace computers is toward computers which look more and more like ground-based machines. Instruction sets compatible with ground-based machines and expanded memory capacity using a hierarchy of storage techniques are examples of this trend.

A technical paper was presented at the Canaveral Council of Technical Societies, Fourth Space Congress.[49]

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(48) State-of-the-Art of Aerospace Digital Computers, 1962-1967, TM-67-1031-1, D. O. Baechler, June 22, 1967.

(49) The Role of Spacecraft Computer on Advanced Manned Missions, Paper presented to the Fourth Space Congress, Cocoa Beach, Fla., April 6, 1967, E. L. Gruman, P. S. Schaenman.

MANNED SPACE FLIGHT COMPUTER UTILIZATION STUDY

TASK ORDER NO. 31

Draft copies of papers describing major problems associated with the use of computers in Manned Space Flight (MSF) facilities are in preparation. A progress report was given to MSF Resources Sharing Panel on June 1, 1967.

ADVANCED LUNAR MISSION STUDIES

TASK ORDER NO. 32

Lunar Orbiter Mission Planning and Operations

With the success of Lunar Orbiters I, II, and III, and the general fulfillment of their Apollo support function, the Orbiter Project assumed a new role of scientific data gathering and support of advanced lunar missions.

A study was made which included an analysis of methods for optimizing the mission lighting conditions despite the large precessional changes expected during the Orbiter IV mission.

As an aid to that study a computer program was developed and computer data outputs were generated in tabulated and graphical forms. These data presentations were used to review the initial mission design and served as the basis for recommended changes prior to the mission. During the mission they were used to check real time Space Flight Operations Facility (SFOF) computations of exposure time. They were also used to predict at which stages in the mission marginal photographic conditions would occur. The computer program was then used as a base for defining the points at which detailed geological inputs should be prepared (e.g., albedo histograms and sectionalization of expected footprints, etc).

Seventy-seven photographic sites (40 prime, 37 secondary) had been proposed by the Orbiter V Mission Planning Working Group. The salient characteristics of those sites were analyzed and presented in both detailed and statistical format.(50) Twenty of those sites were determined to be particularly significant, containing all features and possible combinations represented in the seventy-seven proposed sites.

Advanced Exploration Mission Modes

An inventory of equipments was assembled into a variety of mission modes selected on the basis of hardware availability, use of Apollo technology, and cost effectiveness.(51) Landed payload capabilities were then computed for the spectrum of mission modes and the anticipated problem areas were discussed. The effort was concentrated on the assessment of options suitable to the time span between AAP and the establishment of a semi-permanent lunar base.

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(50) Proposed Sites for Orbiter Mission V: A Preliminary Report, Memorandum for File, Farouk El-Baz, May 15, 1967.

(51) Manned Lunar Program Options - Mission Modes, TM-67-1012-5, C. Bendersky, D. R. Valley, May 5, 1967.

AAP Ad Hoc Lunar Missions Study Team Effort

During the quarter the Advanced Manned Missions Office was supported by participation in the work of an ad hoc study team to develop plans for lunar exploration to be accomplished as part of AAP. Areas of work included interpretation of objectives, review of mission modes, spacecraft configuration and instruments, and evaluation of alternative programs.

A discussion of Apollo lunar mission limitations was undertaken which led to a suggested allocation of weight margin expected to be available on the extended LM.(52) It was concluded that first priority should be given to the use of propellant to accomplish landings to within 100 meters of a predesignated lunar site. Next, surface stay-time should be raised to 3-4 days with 6-8 EVA periods. Since the extended LM missions will emphasize surface sampling, a minimum of 100 lbs returned lunar sample is desirable (150 lbs total return payload including sample containers, film, tape, etc.). Finally, the descent payload including the Apollo Lunar Surface Experiments Package (ALSEP) and the Lunar Geologic Experiment (LGE) should be increased by 125 lbs in order to accommodate a full complement of lunar experiments.

A more detailed consideration was given to improvements to the ALSEP which are desirable in order to make it a more effective and efficient scientific exploration tool for advanced lunar missions.(53) In a minimum modification ALSEP improvements are primarily operational in nature, including delay of assembly as long as feasible to provide maximum flexibility in the experiment complement. Changes in lunar surface timelines are also desirable in order to permit more choice of deployment location and to allow more functional operation before LM ascent. The total number of experiments one would like to do with an emplaced scientific station is not large. Hence a new ALSEP would differ mainly in an increase of about 100 lbs attributable to experiment weights and to flexibility. The new ALSEP would also be useful as a test-bed to check the feasibility of experiments for a future lunar-based interplanetary observatory.

For long duration lunar surface and orbital missions, an investigation was made of the radiation hazard to astronauts. Estimates indicated that LM shielding against solar flares would not provide sufficient protection for surface stay-times longer than a day.(54) An additional one gm/cm^2 will provide sufficient shielding for longer missions or, alternatively, aborts within

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(52) Margin Allocation on Extended LM Lunar Missions, Memorandum for File, N. W. Hinners, June 9, 1967.

(53) Requirements for an Improved ALSEP for the Lunar Exploration Program, Memorandum for File, P. J. Hickson, June 23, 1967.

(54) Effects of Solar Cosmic Ray Activity on AAP Lunar Exploration Missions, Memorandum for File, R. H. Hilberg, May 15, 1967.

10 hours of the onset of solar particles will assure safety in either case. Reduction of exposure and the number of false aborts can be accomplished by use of a warning system.(55) Orbital missions of 35 days (28 in lunar orbit) do not appear particularly hazardous.

The possibility does exist that operational modifications for orbital missions may be desirable during a solar event, such as keeping the thinnest sections of the spacecraft pointed toward the moon.

For the lunar surface exploration programs, various forms of mobility modes such as (a) an astronaut on foot; (b) use of the Lunar Scientific Survey Module (LSSM); and (c) use of the Lunar Flying Vehicle (LFV) are being examined as to their range, capabilities and limitations. Certain inherent advantages are associated with LFV and it appears that this should be given serious consideration.

CSM weight estimates were derived for the extended lunar missions as outlined in the current AAP Ad Hoc Study effort.(56) The weight estimates incorporated increased expendables required for life support, electrical power generation and cabin leakage. In addition, estimates were included for increased RCS requirements and structural penalties. The necessary changes to the spacecraft subsystems were pointed out as critical lead time items as was the necessity of developing instrument payloads and associated weights.

Another aspect of the Ad Hoc Study participation was an investigation of the use of a manned CSM for orbital mission work after assisting in the unmanned landing of a Lunar Payload Module.(57) The allowable CSM inert weight for orbital mission work was determined as well as the possibilities of trading inert weight for SM propellant for orbital maneuvering. Probable mission constraints were discussed, and a potential spectrum of experiments and associated instrumentation was developed to fit within the mission constraints considered.

The role of an orbital mission was examined in the context of a phased lunar exploration program.(58) An initial mission would be devoted primarily to obtaining photographs of scientific landing sites for post Apollo exploration and for feasibility studies of remote sensors.

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(55) Radiation Doses in Lunar Orbit, Memorandum for File, R. H. Hilberg, May 23, 1967.

(56) CSM Requirements for Extended Lunar Missions, TM-67-1012-7, D. R. Valley, June 22, 1967.

(57) Potential Use of the CSM for Lunar Orbital Mission Work, Memorandum for File, C. J. Byrne, W. L. Piotrowski, D. R. Valley, June 4, 1967.

(58) Role of the Orbital Mission Remote Sensors in a Lunar Exploration Plan, Memorandum for File, W. L. Piotrowski, April 21, 1967.

A second orbital mission would have as its principal objective the systematic mapping of the moon with sensors proven out earlier. Based on a 1969 mission for the first orbiter and 1971 for the second, experiment payloads were suggested. A conclusion reached in the study was that the payloads and results are relatively independent, whether or not the missions are manned.

PLANETARY MISSION STUDIES

TASK ORDER NO. 33

Mars

Experiments

A preliminary study was completed which defined possible experiment payloads for an early manned flyby mission to Mars.(59) Experiments were selected to meet a particular set of scientific and technological objectives. The experiment program was divided into the investigation of Mars and an en-route program of space physics and astronomy observations. The Mars exploration plan included the launch of four different types of unmanned probes from the manned vehicle. The conceptual design and performance of each probe type were discussed. The resulting experiment payload weight, including onboard telescopes, a biological laboratory, and all probes was about 35,000 lbs.

Several aspects of this experiment system have been developed further in supporting memoranda. In particular, the objectives and performance of nine different camera systems which make up the Mars flyby mission photography experiment were described.(60) Four of these camera systems operate on board the manned vehicle and the other five are carried on board the probes.

One of these camera systems works in conjunction with a one meter diffraction-limited telescope to be operated by the astronauts to take high resolution photography of Mars during the encounter portion of the flyby mission. An analysis was conducted to show that slewing the line of sight significantly increases the photographic coverage over that obtainable with the telescope in a fixed orientation.(61) While full planet coverage throughout the encounter is not feasible, horizon-to-horizon coverage is possible until approximately 30 minutes prior to periapsis with a 1.7 meter mylar mirror slewing the line of sight.

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(59) Experiment Payloads for a Manned Mars Flyby Mission, TR-67-233-1, F. G. Allen, P. L. Chandeysson, E. M. Grenning, D. B. Hoffman, R. N. Kostoff, M. Liwshitz, W. B. Thompson, May 15, 1967.

(60) Photographic Experiments for Manned Mars Flyby, Memorandum for File, P. L. Chandeysson, May 12, 1967.

(61) Slewing of Telescope Line of Sight to Increase Photographic Coverage on Manned Planetary Flyby Mission, Memorandum for File, C. L. Greer, June 6, 1967.

Probes

The probes which the manned flyby vehicle delivers to Mars are launched several days before planetary encounter. One of these probes is an atmospheric entry device designed for early sampling of atmospheric parameters before the remaining probes arrive. The problem of targeting this probe was investigated.(62) The effect of errors in thrust application both at separation from the manned vehicle and at midcourse correction was considered. It was concluded that reasonable targeting accuracies could be achieved with acceptable propulsion requirements.

A second type of probe is a Mars orbiter. The interaction of this probe with the Mars atmosphere was investigated.(63) An error analysis indicated that the uncertainty in calculating orbiter lifetime is directly proportional to the uncertainty in upper atmosphere density, as measured by an entry probe. The uncertainty is amplified by the ratio of orbiter altitude to the scale height of the atmosphere when lower atmospheric density is measured, as by a radio occultation experiment. This indicated that the atmospheric entry probe could provide valuable data for selecting the orbiter probe altitude.

Mission Operations

An interim mission sequence plan for the encounter portion of a 1975 manned Mars flyby mission was prepared. It provides the basis for defining the role of man on such a mission and provides a focus for identifying mission and systems areas requiring further study.(64)

Venus

Several probe concepts have been identified and initial performance estimates have been made to define an experiment payload for a manned Venus fly-by mission. Probe types include an orbiter, atmospheric entry impacters, weather balloons, reconnaissance atmospheric floater probes, and hard landing surface probes designed to survive for at least one hour. In general these design concepts assume a more hostile and uncertain environment at Venus than at Mars.

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(62) Analysis of Errors in Targeting an Atmospheric Entry Probe for Impact on Mars, TM-67-1014-3, R. N. Kostoff, M. Liwshitz, June 15, 1967.

(63) Interaction of Space Probes with Planetary Atmospheres: I, Memorandum for File, R. N. Kostoff, June 16, 1967.

(64) Interim Mission Sequence Plan for the Encounter Portion of the 1975 Manned Mars Flyby Mission, Memorandum for File, E. M. Grenning, June 15, 1967.

Preliminary experiment payloads for these probes are being defined to investigate the atmosphere, surface, and possibilities of life on Venus.

Payloads were defined and sizes determined for unmanned Venusian entry probes for use in conjunction with the manned multi-planet flyby missions under investigation by the NASA Planetary Joint Action Group.

Eight families of triple-planet flyby missions (Earth-Venus-Mars-Venus-Earth) were found to comprise a one hundred sixty day launch opportunity in late 1976 and early 1977.(65) The opportunity is divided into four two-week windows each having an option of two return dates at Earth. Based on the trajectory characteristics of specific families the 1977 triple-planet flyby should be considered a strong candidate mission for the planetary exploration program.

The 1979 outbound Venus-swingby Mars-stopover mission was compared with the 1975 Mars twilight flyby mission regarding interplanetary abort capabilities.(66) An abort capability was determined to exist for the first twenty-five days of the Venus swingby mission if both Mars retro and escape stages remain functional.

Trajectories

The basic feasibility of sample return to a manned flyby spacecraft by means of rocket launch from the surface of Venus was investigated. It was found that because of the high density atmosphere, combined drag and gravity losses are prohibitive.(67) Sample return from Venus therefore appears to be restricted to the possibility of an atmospheric sample.

Spacecraft and probe trajectories within Venus' sphere of influence were calculated for the 1975 Venus lightside flyby to determine the relation between probe entry angle into Venus' atmosphere, the time and position of the entry point measured from spacecraft periapse, and the ΔV required for the maneuver separating the probe from the flyby spacecraft.(68) It was found that for small ΔV's and reasonable entry angles, the entry point is restricted to a zone of about 30^o in width.

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(65) Families of 1977 Triple-Planet Flybys, Memorandum for File, A. A. VanderVeen, June 6, 1967.

(66) Interplanetary Aborts - the 1979 Venus Swingby vs. the 1975 Mars Flyby Abort Capabilities, Memorandum for File, A. A. VanderVeen, May 22, 1967

(67) 1975 Venus Lightside Flyby - Ascent of Venus Surface Sample Return (VSSR) Probe, Delta V Requirements, Memorandum for File, J. J. Schoch, May 26, 1967.

(68) 1975 Venus Lightside Flyby - Trajectory of Spacecraft and Probes, Memorandum for File, J. J. Schoch, June 7, 1967.

The use of elliptical rather than circular earth orbits for rendezvous and assembly operations was investigated for manned planetary flyby missions. (69) It was found that performance advantages on the order of 40,000 lbs greater payload for the same number of launches could accrue from elliptic orbits.

Using the proposed S-IVC injection stages the performance gains from the use of elliptic orbit rendezvous should permit injection of 200,000 lb. spacecraft on missions to the near planets with four standard Saturn V launches or three launches of an improved Saturn V which incorporates a lengthened first stage plus uprated F-1 and J-2S engines.

Space Vehicle Studies

The effects of nuclear rocket thrust level on weight in earth orbit and on engine operating time were determined for a 1982 manned Mars landing mission based on an upper-bound spacecraft weight of 400,000 lbs. (70)

A parametric preliminary design of a high energy upper stage for use on Saturn V was prepared. (71) The estimated propellant fraction and ΔV capability of several candidate 110,000 lb cryogenic propulsion modules sized to inject a 180,000 lb spacecraft from a highly elliptic earth parking orbit into a heliocentric Mars twilight flyby trajectory are determined. Also considered are alternate missions of varied duration to reflect the stage propellant fraction sensitivity to time and solar flux variables. The concepts selected for point design analysis employ either LH_2/LF_2 or LH_2/LO_2 propellants and are considered in combination with both present and advanced engine systems. A nominal mission duration in earth orbit of 150 days is assumed, consistent with launch buildup requirements of a planetary mission.

Spacecraft Studies

One of the requirements for a low cost integrated planetary and earth orbital space program is considerable commonality of hardware. An economic and program evolution rationale for this development approach was provided. (72)

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(69) Comparisons of Circular and Elliptic Orbit Rendezvous for Manned Planetary Flyby Missions, Memorandum for File, H. S. London, June 8, 1967.

(70) Nuclear Rocket Thrust Level for a Manned Mars Landing Mission, Memorandum for File, H. S. London, J. J. Schoch, June 16, 1967.

(71) Preliminary Design of a Cryogenic Planetary Propulsion Module, TM-67-1013-2, M. H. Skeer, May 10, 1967.

(72) Rationale for the Use of a Planetary Mission Module as an Earth Orbit Mission Module, Memorandum for File, D. Macchia, May 12, 1967.

In particular, the design of a multi-purpose planetary mission module is practical and represents a significant cost saving. With minor modification or additional design requirements the planetary module can slso provide a suitable, cost effective building block for earth orbital missions.

GENERAL MISSION ENGINEERING STUDIES

Numerical studies are in progress which will result in parametric maps of the effects of lunar and solar perturbations on the perigee altitude of elliptic earth parking orbits with orbital inclination as a parameter. The orbits being studied are those whose planes contain the departure asymtotes for the 1975 Mars twilight flyby missions, 1975 Venus lightside flyby, a triple planet Venus-Mars-Venus flyby departing earth late 1976, and a 1977 Venus flyby mission.

A paper was presented to the Society for Industrial and Applied Mathematics on the motion of a flat mirror placed in a near-circular, synchronous earth orbit. (73) Examination of a closed form solution of the motion equations shows the effect of solar radiation pressure to be twofold; the orbit is deformed in a direction perpendicular to the earth-sun line independent of any orbital parameters, and the excursions from the zenith have to be counteracted by thrusting maneuvers which depend on injection conditions. Formulae and numerical values for the ΔV requirements of some of these maneuvers were included.

The results of prior studies of configuration management techniques for computer programs were used to prepare a paper describing the format and content of a computer program specification. The paper was presented to the 1967 Spring Joint Computer Conference. (74)

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(73) Effects of Solar Radiation Pressure on the Motion of an Earth-Orbiting Mirror, Oral Presentation to the Society for Industrial and Applied Mathematics (SIAM), Washington, D.C., June 13, 1967, H. B. Bosch, (Abstract to be published in the SIAM Review).

(74) The Technical Specification - Key to Management Control of Computer Programming, Paper published in AFIPS Conference Proceedings, Vol. 30 (Spring Joint Computer Conference), B. H. Liebowitz, April, 1967.

ENGINEERING SUPPORT

Computing Facility

The UNIVAC 1108 computer installed at the office of the UNIVAC Division, Sperry Rand Corp, Washington, D.C. was used during the report period for conversion of Bellcomm application programs, training, and operating system checkout. After completing this phase of the conversion, the 1108 computer will be installed on Bellcomm premises in place of the current IBM 7040/7044 system.

Utilization of BCMSYS continued at a high level during the period. No major changes were made to the system, and none are anticipated prior to its replacement.

The programming staff provided assistance in the following areas:

(1) Information Storage and Retrieval

(2) Apollo Communications System Capability

(3) Computer-Drawn Flowcharts

(4) LM Autopilot Simulation

(5) Terrain Analysis for LM Guidance

(6) Timeline Analysis for AAP Mission Planning

(7) Spacecraft Weight and Sensitivities Program

(8) Interplanetary Transfer Trajectories

(9) Control Moment Gyro Attitude Control System

(10) Additions to Powered Flight Simulator

(11) Generalized Three-Degree-of-Freedom Autopilot

(12) Orbiting Satellite Lifetime Prediction

(13) Lunar Orbiter Targeting Analysis

(14) Analysis of Electron Energy Measurement Data.

ADMINISTRATIVE

Effective June 15, 1967, R. L. Wagner was appointed Managing Director, Systems Engineering Center, replacing T. H. Thompson who was transferred to the Bell Telephone Laboratories.

LIST OF REPORTS AND MEMORANDA

(Listed in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
The Technical Specification - Key to Management Control of Computer Programming, Paper published in AFIPS Conference Proceedings, Vol. 30 (Spring Joint Computer Conference), B. H. Liebowitz	April 1967
Influence of Space Vehicle Returns to the VAB on Lunar Launch Opportunities, Memorandum for File, D. M. Duty, C. H. Eley III	April 3, 1967
Orbital Altitude Considerations for AAP-4, Memorandum for File, V. J. Esposito	April 5, 1967
The Role of Spacecraft Computer on Advanced Manned Missions, Paper presented to the Fourth Space Congress, Cocoa Beach, Fla., E. L. Gruman, P. S. Schaenman	April 6, 1967
The Effects of Changing the Launch Azimuth Limits on the Launch Window, Launch Vehicle Payload, and Communications and Tracking Coverage, Memorandum for File, T. B. Hoekstra	April 6, 1967
Communications Processor Loading Studies MCC-H CCATS UNIVAC 494 Algorithm, Memorandum for File, R. M. Marella, Bell Telephone Laboratories	April 10, 1967
Tethered LM/ATM Modes for AAP 3/4, Memorandum for File, J. Kranton	April 10, 1967
LM Subsystem Monitoring After Pad Closeout - Apollo/Saturn V, Memorandum for File, D. M. Duty	April 10, 1967
Saturn V Launch Vehicle Engine-Out and Ground Wind Structural Capability, Memorandum for File, H. E. Stephens	April 11, 1967

TITLE	DATE
Experiment for Evaluating a Dynamic Noise Margin Test for the Apollo Guidance Computer, Memorandum for File, J. J. Rocchio	April 13, 1967
Tether Management Considerations for AAP-4, TM-67-1022-1, W. W. Hough	April 13, 1967
Quasi-Inertial Stabilization of the AAP 1/2 Cluster Configuration, TR-67-600-3-1, B. D. Elrod	April 14, 1967
Launch Vehicle Error Analysis for Apollo/Saturn 501 (U), BTL-R-67-310-1, Bell Telephone Laboratories, CONFIDENTIAL	April 14, 1967
A Parametric Study on the Use of Diluent Gases as a Means of Extinguishing Spacecraft Fires in Flight, TM-67-2032-1, L. G. Miller	April 17, 1967
A Description of the S-IC Stage Propellant and Propellant Pressurization Systems, Memorandum for File, S. H. Levine	April 20, 1967
Radiation Effects in the Optical Elements of the Apollo Astrosextant and Scanning Telescope, Memorandum for File, R. H. Hilberg	April 20, 1967
Description of S-II Stage Structures, Memorandum for File, T. H. Crowe	April 20, 1967
Description of S-II Stage Systems, Memorandum for File, T. H. Crowe	April 21, 1967
Role of the Orbital Mission Remote Sensors in a Lunar Exploration Plan, Memorandum for File, W. L. Piotrowski	April 21, 1967
Lunar Surface Models for Apollo, Memorandum for File, W. W. Ennis, F. Heap	April 24, 1967
Memory Requirements for the Launch Vehicle Digital Computer (LVDC), Memorandum for File, J. J. Rocchio	April 25, 1967
Apollo S-Band Communications Capabilities Using High Power RF Modes With Directional and Omnidirectional Antennas, TM-67-2034-3, R. L. Selden	April 26, 1967

TITLE	DATE
Lunar Co-ordinates for Surveyor I, Memorandum for File, C. J. Byrne	April 28, 1967
Data Handling at the GSFC Telemetry Data Processing Facility, Memorandum for File, R. J. Pauly	April 28, 1967
Discussion with MSC on Environmental Control System Tubing Joints, April 27, 1967, Memorandum for File, S. S. Fineblum	May 2, 1967
Analysis of Space Cabin Atmospheres, Memorandum for File, A. E. Hedin	May 4, 1967
Lunar Surface Coordinate Data for Apollo Guidance, Memorandum for File, D. D. Lloyd	May 5, 1967
Manned Lunar Program Options - Mission Modes TM-67-1012-5, C. Bendersky, D. R. Valley	May 5, 1967
Optical Data Processing and Terrain-Hazard Analysis of Lunar Orbiter Photographs, Memorandum for File, V. B. Schneider	May 8, 1967
Coverage Analysis of Missions AAP-1 Through AAP-4 Using Orbit Inclination as a Variable, Memorandum for File, A. G. Weygand	May 9, 1967
Preliminary Design of a Cryogenic Planetary Propulsion Module, TM-67-1013-2, M. H. Skeer	May 10, 1967
Radiation Dose Calculations for AAP Cluster A Missions, Memorandum for File, R. H. Hilberg	May 11, 1967
Rationale for the Use of a Planetary Mission Module as an Earth Orbit Mission Module, Memorandum for File, D. Macchia	May 12, 1967
Photographic Experiments for Manned Mars Flyby, Memorandum for File, P. L. Chandeysson	May 12, 1967
Accumulation of Momentum and CMG Loading for Two Cluster Configurations, Memorandum for File, C. O. Guffee	May 15, 1967
Proposed Sites For Orbiter Mission V: A Preliminary Report, Memorandum for File, Farouk El-Baz	May 15, 1967

TITLE	DATE
LM-Earth S-Band Communications for Powered Descent and Ascent Phases of the Lunar Mission, TM-67-2013-3, A. C. Merritt	May 15, 1967
Effects of Solar Cosmic Ray Activity on AAP Lunar Exploration Missions, Memorandum for File, R. H. Hilberg	May 15, 1967
Experiment Payloads for a Manned Mars Flyby Mission, TR-67-233-1, F. G. Allen, P. L. Chandeysson, E. M. Grenning, D. B. Hoffman, R. N. Kostoff, M. Liwshitz, W. B. Thompson	May 15, 1967
S-IVB/J-2 Engine Restart, Memorandum for File, A. T. Ackerman	May 15, 1967
Interplanetary Aborts - The 1979 Venus Swingby vs. The 1975 Mars Flyby Abort Capabilities, Memorandum for File, A. A. VanderVeen	May 22, 1967
Radiation Doses in Lunar Orbit, Memorandum for File, R. H. Hilberg	May 23, 1967
Variation in Radiation Dose Rate with Altitude and Shielding Thickness at Orbits Near Synchronous, TM-67-1021-1, T. C. Tweedie, Jr.	May 23, 1967
Investigation of Payload Effect of Canting The S-IC Engines, Memorandum for File, W. R. Thomson	May 25, 1967
The Influence of Earth Launch and Lunar Lighting Constraints on the Apollo Mission, TM-67-2013-4, L. P. Gieseler	May 26, 1967
1975 Venus Lightside Flyby-Ascent of Venus Surface Sample Return (VSSR) Probe, Delta V Requirements, Memorandum for File, J. J. Schoch	May 26, 1967
Potential Use of the CSM for Lunar Orbital Mission Work, Memorandum for File, C. J. Byrne, W. L. Piotrowski, D. R. Valley	June 4, 1967
Failure Impact and Backup Capability of Saturn Launch Support ESE at KSC, TM-67-2032-2, V. Muller	June 5, 1967

TITLE	DATE
Families of 1977 Triple-Planet Flybys, Memorandum for File, A. A. VanderVeen	June 6, 1967
Slewing of Telescope Line of Sight to Increase Photographic Coverage on Manned Planetary Flyby Mission, Memorandum of File, C. L. Greer	June 6, 1967
Limitations on Angular Resolution of Optical Telescopes, Memorandum for File, A. E. Hedin	June 6, 1967
1975 Venus Lightside Flyby Trajectory of Spacecraft and Probes, Memorandum for File, J. J. Schoch	June 7, 1967
Comparisons of Circular and Elliptic Orbit Rendezvous for Manned Planetary Flyby Missions, Memorandum for File, H. S. London	June 8, 1967
Margin Allocation on Extended LM Lunar Missions, Memorandum for File, N. W. Hinners	June 9, 1967
Effects of Solar Radiation Pressure on the Motion of an Earth-Orbiting Mirror, Oral Presentation to the Society for Industrial and Applied Mathematics (SIAM), Washington, D.C., H. B. Bosch, Abstract to be published in the SIAM Review	June 13, 1967
Midcourse Correction Penalties Due to Expected Translunar Injection Deviations, TM-67-2012-2, D. A. Corey, B. G. Niedfeldt	June 14, 1967
Interim Mission Sequence Plan for the Encounter Portion of the 1975 Manned Mars Flyby Mission, Memorandum for File, E. M. Grenning	June 15, 1967
Analysis of Errors in Targeting an Atmospheric Entry Probe for Impact on Mars, TM-67-1014-3, R. N. Kostoff, M. Liwshitz	June 15, 1967
Unified S-Band Circuit Margins for the High-Altitude Phase of Mission AS-501, Memorandum for File, J. E. Johnson, J. P. Maloy	June 15, 1967
Nuclear Rocket Thrust Level for a Manned Mars Landing Mission, Memorandum for File, H. S. London, J. J. Schoch	June 16, 1967
A Plan for Modifications to the Voice Conferencing Arrangements at Kennedy Space Center, Bell Telephone Laboratories, Attachment A to J. Z. Menard Memorandum to W. E. Parsons - NASA/MJ of June 16, 1967	June 16, 1967

TITLE	DATE
KSC Conferencing System - Analysis of Transmission, May 26, 1967, Bell Telephone Laboratories, Attachment B to J. Z. Menard Memorandum to W. E. Parsons - NASA/MJ of June 16, 1967	June 16, 1967
Interaction of Space Probes with Planetary Atmospheres: I, Memorandum for File, R. N. Kostoff	June 16, 1967
The Surveyor III Mission and Its Relation to Apollo, Memorandum for File, F. N. Schmidt	June 19, 1967
LM Hold and Recycle Capabilities for Launch Complex 39, Memorandum for File, D. M. Duty	June 19, 1967
Launch Vehicle Digital Computer (LVDC) Requirements for the Apollo Applications Program, Memorandum for File, J. J. Rocchio	June 20, 1967
CSM Requirements for Extended Lunar Missions, TM-67-1012-7, D. R. Valley	June 22, 1967
State-of-the-Art of Aerospace Digital Computers, 1962-1967, TM-67-1031-1, D. O. Baechler	June 22, 1967
Requirements for an Improved ALSEP for the Lunar Exploration Program, Memorandum for File, P. J. Hickson	June 23, 1967
Summary of Apollo 4 (AS-501) Spacecraft Impact Points, Memorandum for File, R. E. Driscoll	June 26, 1967
AAP Experiment Assignments, Memorandum for File, M. S. Feldman	June 27, 1967
Summary of the Data Links From the Apollo Applications Spacecraft to the Manned Space Flight Network for AAP Missions 1-4, Memorandum for File, R. L. Selden	June 30, 1967
Spectral Analysis of A Communications Relay System Using an Apollo Unified S-Band Transponder, TM-67-2034-4, W. D. Wynn	June 30, 1967
Spacecraft Presentation - AAP Lunar Mission Ad Hoc Study Team, Memorandum for File, J. E. Waldo	July 6, 1967

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F. B. Benjamin - MM
J. Bollerud - MM
J. W. Humphreys - MM
E. J. McLaughlin - MM

J. F. Lederer - MO
J. D. Stevenson - MO
W. E. Miller - MOG
B. P. Brown - MOR

R. A. Diaz - MPF
N. Rafel - MPP
B. L. Johnson - MPR

P. E. Cotton - MS
S. A. Cariski - MSP
D. A. Linn - MSP
E. T. Maruszewski - MSP
J. Costantino - MSR
C. H. Pace - MSR

G. S. Trimble - MT
D. R. Lord - MTD
R. F. Lovelett - MTE
M. J. Raffensperger - MTE
J. E. McDonald - MTP
E. W. Hall - MTS
A. D. Schnyer - MTV
F. P. Dixon - MTY

W. L. Jones - RD
F. J. Sullivan - RE
R. D. Ginter - RF
W. H. Woodward - RN
A. O. Tischler - RP
M. B. Ames - RV
L. Jaffe - SA
O. E. Reynolds - SB
E. M. Cortright - SD
G. H. Hage - SE
J. L. Mitchell - SG
O. W. Nicks - SL
R. J. Allenby - SM
W. B. Foster - SM
J. E. Naugle - SS
V. L. Johnson - SV

NASA-KSC

K. H. Debus - AA
J. C. Wooten - DB
R. C. Hock - DF
W. T. Clearman - DG
R. O. Middleton - DG
S. E. McCoy - DJ-1
S. P. Hale - EB
R. A. Petrone - HA

NASA-MSC

R. R. Gilruth - AA
J. M. West - AD
D. K. Slayton - CA
M. A. Faget - EA
R. O. Piland - EX
C. C. Kraft - FA
R. F. Thompson - KA
G. M. Low - PA
O. G. Morris - PE
R. W. Lanzkron - PF
M. Dell - PP
W. B. Kelly - PP
J. T. Markley - PA
A. Liccardi - RASPO/Bethpage

NASA-MSFC

W. vonBraun - DIR
E. F. O'Connor - I-DIR
W. A. Mrazek - I-DIR
W. Teir - I-IB-MGR
P. Dunlap - I-I/IB-G
R. L. Goldston - I-RM-M
L. F. Belew - I-S/AA
L. B. Bell - I-V-E
S. E. Smith - I-V-G
A. L. Rudolph - I-V-MGR
F. L. Williams - R-AS-DIR
F. S. Wojtalik - R-ASTR-N
H. K. Weidner - R-DIR
J. V. Klima - R-OM-C
L. Richard - R-TO-DIR

NASA-ARC

L. Roberts - M(OART)